DETERMINATION OF SOME PHYSICAL PROPERTIES OF IMMATURE RUNNER BEAN (*PHASEOLUS COCCINEUS)* PODS

J. U. Etoamaihe,[1*] and C. U. Egbu,[2] and A. N. Agriga

[1]*Department of Agricultural and Bio-resources Engineering, Michael Okpara University of Agriculture Umudike, P.M.B. 7267 Umuahia Abia State, Nigeria*

[3]*Department of Food Science and Technology, Federal University Oye-Ekiti, Ekiti State, Nigeria*

***Corresponding author's e-mail address:** jeto50@yahoo.co.uk*

Abstract

Some physical properties of immature Runner beans pods (*Phaseolus coccineus)* were investigated with the aim of using the properties to develop efficient processing machines for the crop. The investigations were done using a digital weighing balance, Vernier calipers and an inclined plane. The results of the investigations showed that the immature pods have moisture content of 89.5%wb, geometric mean diameter of 10.5 mm, the sphericity as 0.45 and the coefficient of friction of the pods on three different surfaces are, plane wood (0.76), stainless sheet (0.84) and glass (0.63), while the bulk density was obtained as 0.77g/cm^3.The pods are likely to slide more on a stainless steel hopper during processing than in any other material tested.

Key words: *Phaseolus coccineus*, pods, mechanical, physical, properties.

1. Introduction

Phaseolus coccineus also known as runner bean, stick bean, or multiflora bean is a legume of the family *Fabaceae* which originated from the mountains of Central America (Aremu *et al.,* 2010) Its vine can grow up to 3m or more in length. Harvesting of green pods starts around 3 months after sowing and lasts for 2 to 3 weeks. Mature seeds can be harvested 4 – 5 months after sowing. *Phaseolus* comprises of about 50 species, most of them are grown in the United States of America (Aremu *et al.,* 2010 and Wikipedia 2015). Phaseolus *coccineus* has been known to be important to mankind in various ways. Almost all the parts of the crop can be used for medicinal purposes. The young pods, leaves and shoots are used as fodder. In Central America the immature and mature seeds are consumed. Preparation is predominantly by boiling. In temperate regions the immature pods are most commonly eaten, sliced and cooked, as a vegetable. In Central America the young shoots, leaves and inflorescences are sometimes used (boiled or boiled and fried) as a vegetable while the tuberous roots are consumed boiled or chewed as candy. A root decoction made from the plant is taken against malaria or applied to swollen eyes for relief of pains and inflammation. In Central America scarlet runner bean is grazed by livestock and can be dried into hay (Brink, 2006). The seed flour is a very rich source of protein in Nigerian meals (Aremu *et al.*, 2006 and Aremu *et al.,* 2010).

The seeds contain some antinutritional elements, such as trypsin inhibitors, and must be cooked before eaten, to break down these compounds. Holland *et al*., 1991 stated that 100 g of the edible portion of the raw green pods contain: Water 91.2 g, Energy 93 kJ (22 kcal), Protein 1.6 g, Fat 0.4 g, Carbohydrate 3.2 g, Fibre 2.6 g, Calcium 33 mg, Magnesium 19 mg, Phosphorus 34 mg, Iron 1.2 mg, Zinc 0.2 mg, Carotene 145 μg, Thiamin 0.06 mg, Riboflavin 0.03 mg, Niacin trace and Ascorbic acid 18 mg. Many improved cultivars have substantially reduced fibrous vascular strands of the pod sutures ('stringless runner beans'). The tuberous root of scarlet runner bean is edible, but it is fibrous and may contain toxic compounds, which can be removed by soaking or peeling and by discarding the cooking water. In the Eastern part of Nigeria, the crops are mainly eaten with the pods when they are green or immature.

Coccinin, a peptide isolated from the seed of scarlet runner bean, has shown a significant antifungal activity against a range of fungi. It also inhibited proliferation of leukaemia cell lines and reduced the activity of HIV-1 reverse transcriptase (Brink, 2006).

Physical and mechanical properties are important in many problems associated with the design of machines and the analysis of the behaviour of the product during agricultural process operations, such as handling, planting, harvesting, threshing, cleaning, sorting and drying. The solutions to problems of these processes involve knowledge of their physical and engineering properties (Irtwange, 2000). This was corroborated by Kutte (2001), who stated that in the design of any agricultural handling and processing machine, properties of the crop must be taken into account. Such properties include; size, shape, mass, moisture content and bulk density.

Bulk densities are essential in knowing the weight of the crop per unit volume and is also useful in handling operations. Volume considerations have practical applications where shape affects the process such as separation and product loading, while weight considerations have practical applications in unit operations such as conveying as well as cleaning. Weight and volume are also useful in mathematical and computer modelling of handling and processing operations where the behaviour of the bulk system is predicted from the microscopic behaviour of individual seed (Rong *et al*., 1995; Raji and Favier, 2004).

Handling losses of crops during processing are affected by size and shape. Coefficient and angle of friction have applications in problems of flow of bulk granular materials especially in calculating hopper sidewall slope angle. Coefficient of friction is important in studying the compressibility of the material and determining methods of compressing and packaging. The other important physical and engineering properties and their significance in machine design and handling are; friction for flow of bulk granular materials, rupture force, aerodynamic properties requiring a knowledge of density, size, shape and drag coefficient for separation and conveyance.

Many researchers have described and worked on the determination of these properties for a number of crops and food materials which include locust bean (Oje, 1993), sorghum (Dev *et al*.,1982), pigeon pea (Chowde-Gowda *et al*., 1991), oil bean seeds (Oje and Ugbor, 1991), breadfruits seeds (Orji, 2000) and pumpkin seeds and kernel (Joshi *et al*.,1993). A comprehensive report of these properties is also presented by Mohsenin (1986). There is, however, very little data on the physical and engineering properties of *Phaseolus coccineus* pod in available literature. There is, therefore, a need for a comprehensive study of these properties to aid the design of processing and handling machines for the crop. This work is focused on the determination of some physical and mechanical properties of the pod of *P.coccineus* with a view to obtaining information required to ease the operations of its processing. Since the runner bean is mostly consumed when the pods are immature together with the seeds, this study becomes very useful. The runner bean is shown in Fig 1.

Fig. 1: *Phaseolus coccineus* pods

2. Methodology

2.1 Moisture Content

The immature pods were harvested after 2months of planting from a garden in Hopeville Uturu, Isuikwuato L.G.A Abia State, Nigeria. The moisture content was determined using ASABE standard S358.2 (ASABE 2011) with an electric oven as shown in equation 1;

$$MC(\%wb) = \frac{w_1 - w_2}{w_1} \times 100 \qquad (1)$$

Where: MC = moisture content (*%wb)*; w_1 = initial weight of pod (g); w_2 = final weight of pod (g).

2.2 Size and Shape

A Withwort model vernier calipers of range 0-150mm, was used to measure the axial dimensions of the pods; length, width and thickness. From the axial dimensions, the geometric mean diameter (D_p) in mm and sphericity (ψ) were determined by using the equations 2 and 3 according to (Frontezak and Metzgen 1985; Joshi *et al*. 1993; Akaaimo and Raji, 2006, Etoamaihe and Ojukwu 2008. The sphericity determines the shape of materials, while the axial dimensions give an indication of the size.

$$D_p = (abc)^{1/3} \qquad (2)$$

Where: a = length (mm); b = width (mm); c = thickness (mm).

$$\psi = \frac{(abc)^{1/3}}{a} \qquad (3)$$

2.3 Density of Pod

The weight (W_p) of the individual pods was determined by weighing them using Cammry ACS-50 digital weighing balance of range 0-500gms and the volume (V_p) determined using water displacement method by pouring water into a Pyrex 250 ml measuring cylinder and immersing the pod into it and the volume of water displaced was determined. The density was therefore calculated using equation 4 below;

$$\rho_p = \frac{W_p}{V_p} \qquad (4)$$

Where: ρ_p = density of pod (g/cm^3).

2.4 Coefficient of Friction on Some Material Surfaces

The coefficient of friction on some material surfaces was determined using an inclined plane as shown in Fig.2.The angle at which the pod starts sliding on the inclined plane is recorded. The experiment was conducted on three material surfaces; these are plane wood, metal sheet and glass. The experiments were replicated five times for each surface and the average of the results obtained for the five replications was taken as the representative value for each surface. The coefficient of friction on material surface was calculated as the ratio of height to the corresponding base of the apparatus using Eqn 5.

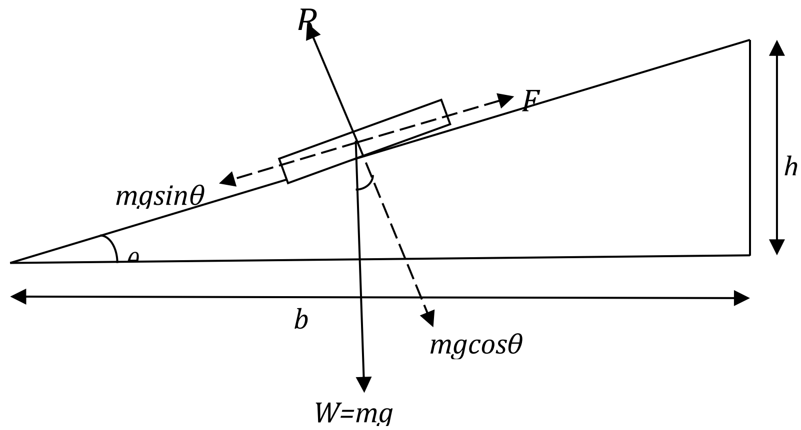

Fig. 2: Coefficient of friction on inclined plane

$$\mu = \frac{h}{b} = \tan\theta \qquad (5)$$

where: μ = coefficient of friction
Θ = angle of inclination of the surface.

3. Results and Discussion

The moisture content of pods used were between the ranges of 89.4 – 89.6% wet basis. The results of the tests performed are presented in Table 1. The results showed that the length, width and thickness for the pods ranged between 20.8 – 26 mm, 6.6 – 9 mm and 5 - 6.8 mm respectively, while the geometric mean diameter and sphericity ranged between 10.5 – 11 mm and 0.45 – 0.5 respectively. This is within the range of 0.32 – 1.00 for sphericity as reported by Mohsenin (1986) for most agricultural particles. On the other hand, *Prosopis africana* pod has the length, width, thickness, geometric mean and sphericity as: 132.46 mm, 28.71 mm, 19.0 mm, 41.39 mm and 0.32 respectively (Adigun and Alonge, 2000). It was observed that each pod of *P. coccineus* contains an average of 19 seeds.

Table 1: Some Physical Properties Data of Immature *Phaseolus coccineus* Pod

Property/unit measurement	Replication	Mean value	Std. Dev.	Max value	Min value
Moisture content (%)	5	89.5	0.14	89.6	89.4
Length (mm)	5	23.6	2.47	26	20.8
Width (mm)	5	8.02	1.03	9	6.6
Thickness (mm)	5	6.12	0.74	6.8	5
Geometric mean (mm)	5	10.5	1.15	11.43	8.82
Sphericity	5	0.45	0.036	0.48	0.41
Mass (g)	5	6.62	1.98	8.18	3.72
Volume (cm^3)	5	8.6	2.19	10	5
Density (g/cm^3)	5	0.77	0.2	1.02	0.542
Coefficient of friction on:					
Plane wood	5	0.76	0.043	0.82	0.73
Metal sheet	5	0.84	0.023	0.86	0.82
Glass	5	0.63	0.055	0.68	0.55

The difference in the axial dimensions for the pod with the relatively low sphericity of 0.45 shows that the pod will not rotate easily during handling. The closer the sphericity to 1.0, the higher the tendency to roll about any of the three axes.

The mass of the pods of *P.coccineus* ranges from 3.72 g – 8.18 g, volume of range 5 cm^3 – 10 cm^3 and density of 0.542 g/cm^3 – 1.02 g/cm^3 while Adigun and Alonge (2000) published that the pods of *Prosopis africana* have mass , volume and density of 24.72 g, 53.43 cm^3 and 0.47 g/cm^3 respectively. The coefficient of friction obtained on plane wood, metal sheet and glass surface for the pods are; 0.73 – 0.82, 0.82 – 0.86 and 0.55 – 0.68 respectively. These values compare well those obtained for the grains of *Prosopis africana* according to Adigun and Alonge (2000) as: plywood (0.65), galvanised steel (0.71) and glass (0.69). African yam bean on aluminum sheet (0.32) by Irtwange and Igbeka (2002) and those obtained by Taser *et al*. (2005) for vetch seed on hardwood sheet (0.29), galvanised sheet (0.30), mild steel and chipboard (0.33). The coefficient of friction of the seed on galvanised sheet compares with what Oje and Ugbor (1991) obtained for oilseed bean on glass (0.29). The coefficient of friction of the pods of *P.coccineus* on the three surfaces of plane wood, metal sheet and glass in relation to the mass is illustrated in Figure 3 below.

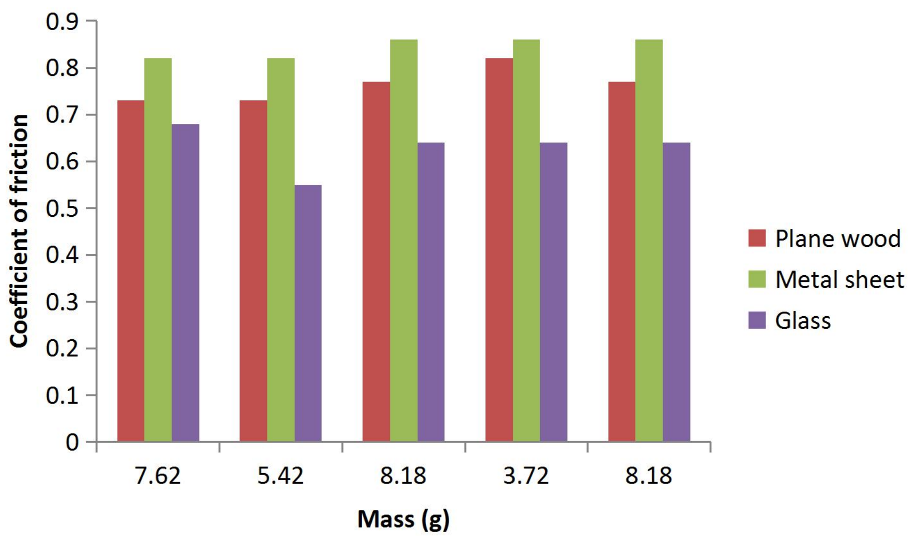

Figure 3: Coefficient of friction of *P.coccineus* on plane wood, metal sheet and glass surface

4. Conclusion

Having carried out investigations on some properties of Phaseolus *coccineus* pod, it can be concluded that the results have shown good agreement with some of the general trend and ranges obtained for other similar crops. The dimensions of the pods are relatively uniform hence will make the processing of the pods easy. The properties are also a good data source, which will be useful in the design and development of the necessary processing machines for the crop. This will help in using appropriate data instead of using properties of similar crops in machine and process design of the crop.

References

Adigun, YJ. and Alonge, AF. 2000. Some Engineering Properties of *Prosopis africana* Pods Relevant to Dehulling. Nigerian Journal of Technology. 19(1): 52-58.

Akaaimo, DI. and Raji, AO. 2006. Some Physical and Engineering Properties of *Prosopis africana* Seed. Biosystems Engineering,95(2):197-205.

Aremu, MO., Olaofe, O. and Akintayo, ET. 2006. Compositional Evaluation of Cowpea (*vigna ungulculata*) and Scarlet Runner Beans (*Phaseolus coccineus*) Varieties Grown in Nigeria. Journal of Food Agric.and Environment. 4(2): 39-43.

Aremu, MO., Olaofe, O., Basu, SK., Abdulazeez, G. and Acharya, SN. 2010. Processed Cranberry Bean (*Phaseolus coccineus*) Seed Flour for the African Diet. Canadian Journal of Plant Sci. 90:719-728.

ASABE 2011. ASAE S358.2 DEC 1988 (R2008). Moisture Measurement – Forages. In ASABE Standards, American Society of Agricultural and Biological Engineers. 608 St Joseph, M.I, U.S.A. 781.

Brink, M. 2006. *Phaseolus coccineus* L. In: Brink, M. and Belay, G. (Editors). PROTA 1: Cereals and Pulses/Cereales et legumes secs. [CD-ROM]. PROTA, Wageningen, Netherlands.

Chowde-Gowda, M., Ramaiah, R. and Banakar, AS. 1991. Engineering Properties of Pigeon pea Seeds. Mysore Journal of Agricultural Science, 25(2): 224-228.

Dev, DK. Satwadhar, PN. and Ingle, VM. 1982. Effect of Variety and Moisture on Certain Selected Physical Properties of Sorghum Grain. Journal of Agricultural Engineering, 19(2):43-48.

Etoamaihe, UJ. and Ojukwu, NS. 2008. Determination of Some Selected Physical Properties of Three Cassava Tuber Varieties. Proceedings of Nigerian Institution of Agricultural Engineers. South East Regional Conference Awka 2008. 108 – 115.

Frontezak, J. and Metzgen, T. 1985. The Studies in Slip Angle and Geometrical Features of Corn Grain in Moisture Function. Proceedings of the Third International Conference on Physical Properties of Agricultural Materials, Prague. 239-244.

Holland, B. Unwin, ID. and Buss, DH. 1991. Vegetables, Herbs and Spices. The Fifth Supplement to McCance & Widdowson's The Composition of Foods. 4th Edition. Royal Society of Chemistry, Cambridge, United Kingdom. 163.

Ige, MT. 1977. Measurement of Some Parameters Affecting the Handling Losses of Some Varieties of Cowpea. Journal of Agricultural Engineering Research, 22:127-133.

Irtwange, SV. 2000. The Effect of Accession on Some Physical and Engineering Properties of African Yam Bean. Unpublished PhD Thesis, Department of Agricultural Engineering, University of Ibadan, Nigeria.

Irtwange, SV. and Igbeka, JC. 2002. Some Physical Properties of two African Yam Bean (*Sphenostylis stenocarpa*) Accessions and their Interrelations with Moisture Content. Applied Engineering in Agriculture, 18(5): 567-576.

Joshi, DC., Das, SK. and Mukherjiee, RK. 1993. Physical Properties of Pumpkin Seeds. Journal of Agricultural Engineering Research, 54(3): 219-229.

Kutte, MT. 2001. Reactivation and Performance Evaluation of the Threshing Unit of a Combined Harvester for Stationary Threshing of Rice. Unpublished M. Eng Thesis, Federal University of Technology, Yola, Nigeria.

Leung, WT. Busson, F. and Jardin, C. 1968. Food Composition Table for Use in Africa. FAO, Rome, Italy. 306.

Mohsenin, NN. 1986. Physical Properties of Plant and Animal Materials: Structure, Physical Characteristics and Mechanical Properties. Updated and Revised Edition. Gordon and Breach Science Publishers, New York.

Oje, K. 1993. Locust Bean Pods and Seeds: Some Physical Properties of Relevance to Dehulling and Seed Processing. Journal of Food Science and Technology, Mysore. 30(4):253-255.

Oje, K. and Ugbor, EC. 1991. Some Physical Properties of Oil Bean Seed. Journal of Agricultural. Engineering Research. 50(4): 305-313.

Orji, CU. 2000. Evaluation of the Physical Properties of Breadfruit Seeds (*Treculia africana*) Necessary for Shelling. Journal of Agricultural Engineering and Technology. 8: 55-58.

Raji, A.O. and Favier, JF. 2004. Model for the Deformation in Agricultural and Food Particulate Materials Under Bulk Compressive Loading Using Discrete Element Method - II: Compression of Oilseeds. Journal of Food Engineering, 64: 373-380.

Rong, G. Negi, SC. and Jofriet, JC. 1995. Simulation of the Flow Behaviour of Bulk Solids in Bins - Part 2: Shear Bands, Flow, Corrective Inserts and Velocity Profile. Journal of Agricultural Engineering Research, 62: 257-269.

Taser, OF., Altuntas, E. and Ozgoz, E. 2005. Physical Properties of Hungarian and Common Vetch Seeds. Journal of Applied Science, 5(2): 323-326.

Wikipedia 2015. *Phaseolus coccineus*. www.wikipedia.org/wiki/*Phaseolus_coccineus*. Date accessed; 1st August, 2015.